SERC 2012 ANNUAL REPORT

SYSTEMS ENGINEERING
Research Center

A US Department of Defense University Affiliated Research Center

Report Documentation Page

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SYSTEMS ENGINEERING
Research Center

CONTENTS

Focusing on Transition

As our world changes, we are constantly in transition—moving from one state to another with the desire to reach higher effectiveness and greater impact. Transitions are often marked by a period of change between one set of circumstances and another, to incorporate new realities. Living with transition leads to uncertainty, which in turn calls for rapid responses, agility, and flexibility to take advantage of the benefits of new ideas and approaches.

The SERC embodies transition. It was created to transition systems engineering research into an increasingly uncertain and complex environment. SERC researchers create knowledge through research, and then create ways to disseminate that knowledge to practitioners.

SERC success is measured by demonstrable effect, not just publications and tools. Achieving the desired impact means achieving successful transition of systems research to people, process, technology, and practice. To reach that goal, our transition relationships must include leaders, policy makers, and practitioners within government and industry.

SERC uses a variety of transition channels. The primary channel is through our sponsors and their existing projects and programs. Seminars, workshops, and pilots that address specific projects are key to evaluating and improving research-inspired practice.

Our second channel is through the academic programs at our member universities and other research partners. By including research results and transitional tools within each university's curriculum, the research can become part of the fabric of fundamental education for systems and software engineers.

A third channel includes publications and public involvement. SERC reports, journal articles and conference papers provide a platform for presenting, discussing, and refining our research. Working groups and industry, academic and professional societies can actively support transitioning that research at the grass roots level.

Transition also occurs in relationships, and the SERC is evolving in terms of the organizations it works with and the roles it takes. We are collaborating with new organizations and in new ways.

The creation of the SERC Doctoral Fellows program provides not only for substantive contribution to SERC research by the very best in industry and government through their doctoral research, but also builds a direct channel back to their organizations for transitioning SERC research into application and practice.

We are more closely coordinating with other UARCs and FFRDCs that directly support defense programs. The result is more tailored research directly reaching critical acquisition and sustainment activities and better feedback on research-product applicability, affordability, and effectiveness. We have established closer relationships with non-defense government organizations as well. Opportunities for broader collaboration include populating and testing the experience accelerator, mining data, and co-sponsoring or exchanging doctoral fellows.

The SERC is proud of its role transitioning new systems engineering capabilities and approaches to the defense community. We believe that research needs application to both validate the work and disseminate the findings. This transition function helps the SERC propel the practice of systems engineering, architecting, and thinking to greater levels of effectiveness.

FROM THE DIRECTOR

I am pleased to provide the SERC Annual Report for 2012. This has been an exciting and fruitful year. Having refined and solidified our vision in 2011, we have enthusiastically embraced it throughout our activities, and are making strides toward becoming the Systems Research and Impact Network.

We have expanded our collaborator community by adding North Carolina Agricultural and Technical University and Georgetown University as new members. We have enabled founding members MIT and University of California San Diego to fully participate through changes in the SERC's contract. Those changes also provide a means for the SERC to participate in classified work as necessary.

We have worked diligently to ensure future impact by broadening our sponsor base. A new agreement with the Federal Aviation Administration is applying SERC researchers to the complex NextGen air traffic control system program. We are increasing the impact of SERC research throughout the systems engineering community through closer relationships with our sponsors and additional transition channels. We have welcomed new members to the SERC Advisory Board as we said farewell to some initial members who so ably supported us and have moved on to other challenges.

Above all, we are enthusiastically tackling the systems problems brought to us by our sponsors. This report provides a window into the wide variety of SERC research—projects that are already transitioning, work that is underway, and concepts just initiated or in the pipeline.

Dinesh Verma

FROM THE HONORABLE ZACHARY J. LEMNIOS

Our nation faces an uncertain world, with increasing complexity, fiscal austerity, creative adversaries, and easy access to technology. The innovative thinking that the SERC brings to the table addresses today's complex and changing socio-technical systems in a serious way. An understanding of systems engineering and its relation to health care, transportation, and energy is vitally important to the Department of Defense. The SERC is key to addressing these challenges, working to:

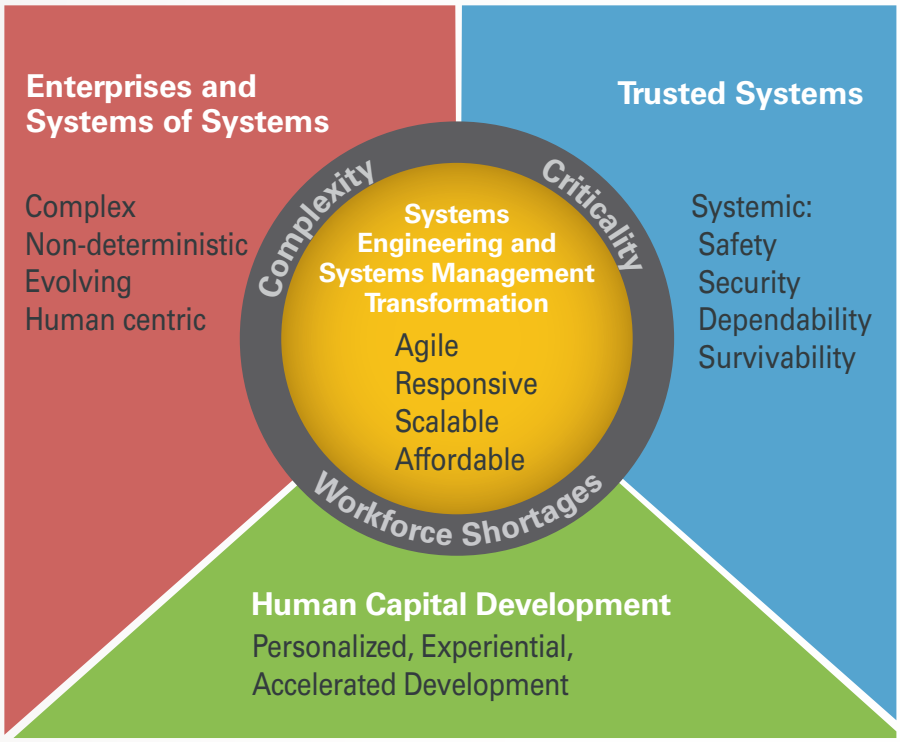
- Ensure systems engineering stays relevant in an increasingly complex world—a world that requires systems to respond rapidly to changing threats.
- Leverage systems engineering and engineered resilient systems to maintain an advantage over future adversaries—foes with access to advanced technology and low barriers of entry.
- Rapidly field systems that can respond and interoperate with legacy assets—assets that will be forced to operate longer than planned and perform in new environments for which they were not developed.
- Prepare the workforce of the future to help us solve these complex problems, and new ones that we cannot even imagine today—a workforce fluent in systems thinking and systems development, with multidisciplinary science and engineering capabilities.

I appreciate the contributions of all of the SERC universities, the collaborators, and the many students who are engaging in this work. I look forward to our ongoing collaboration.

Zach

Embodying the SERC Vision

Throughout 2012, the SERC has lived out the new vision of becoming the Systems Research and Impact Network. The fundamental SERC strategic plan was conceived, adopted, and approved at the end of 2011. We want to share the progress we have made toward achieving each of the strategies in the 2011 Plan.



EXPAND AND SUSTAIN CRITICAL SPONSOR RELATIONSHIPS

Our relationships with our DAU/OSD sponsors are exceptionally strong, and continue to be catalytic and collaborative, as well as carefully managed and challenging. Our sponsors are involved in selecting, planning, and executing research tasks, as well as evaluating the results and supporting transition. Contract changes have made it possible for the SERC to take on classified work, which opens an entirely new vector for research, observation, analysis, and transition.

Expanding our sponsor base has been a key goal throughout SERC's existence. This past year, we have implemented a contract with FAA as a pathfinder for non-OSD sponsors, and believe it to be just the first of several new government sponsors. This is critical if SERC is to become the national resource represented in the vision.

STRENGTHEN RESEARCH ECOSYSTEM

By establishing a broad range of projects and presenting research in diverse settings, the reputation of the SERC has expanded and become more visible to systems researchers. We find that more people want to be involved in SERC activities because SERC is now part of the fabric of SE research. One illustration of this is the prevalence of SERC research papers at the annual Conference on Systems Engineering Research (CSER) held last year in St. Louis. More about the SERC's influence on CSER can be found on page 5.

Since its inception, over 350 researchers have been engaged in SERC projects. This includes a growing number of undergraduates involved in research and support activities. We believe the impact of participation on their understanding of systems research will be an effective impetus to their using new technology as it arises, as well as their future participation in academic and industry research.

This year, we established a SERC Doctoral Fellows program to expand SERC visibility throughout the systems engineering community in defense, aerospace, and other industries. More about the Doctoral Fellows program appears on Page 4.

Research Areas Icons

- ENTERPRISE & SYSTEMS OF SYSTEMS
- TRUSTED SYSTEMS
- HUMAN CAPITAL DEVELOPMENT
- SE & SM TRANSFORMATION

STRATEGIC COMMUNICATIONS

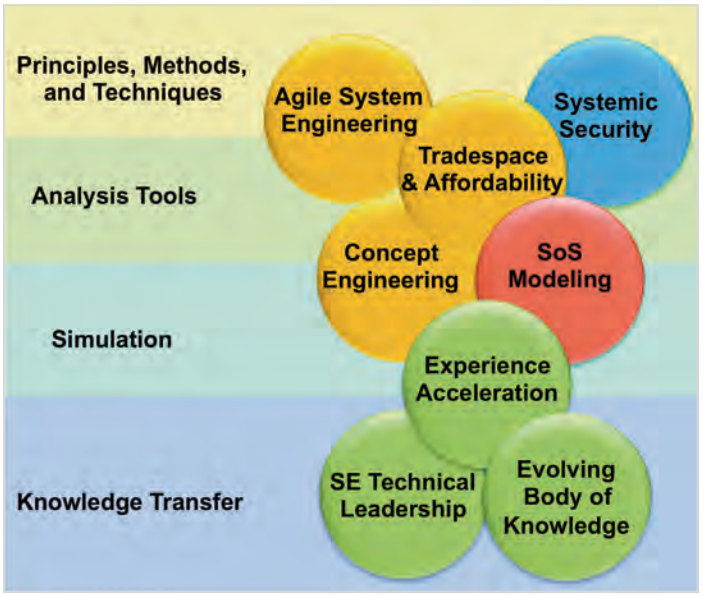
The transformation of the Annual SERC Research Review from a traditional conference to a sequence of specialized events was a key factor supporting the evolution of the research ecosystem and enhancing the relationship with our sponsors. Leveraging SERC's position within CSER yielded a synergistic way to both satisfy the technical reporting sponsors need and gain a broader audience for the research while eliminating expensive redundancy in travel and time. SERC will continue to look for ways to use conferences in this manner. More information on this year's activities is provided on page 5.

SERC also continues to increase its participation in the International Council on Systems Engineering (INCOSE), Institute of Electrical and Electronics Engineers (IEEE), and National Defense Industrial Association (NDIA). SERC members are involved in high-level initiatives including INCOSE's Agile Systems Engineering and SE Vision 2015 projects, and IEEE's collaboration with PMI in developing a Software Extension for the Guide to the Project Management Body Of Knowledge. The SERC-led SE Body of Knowledge and Curriculum work (known as BKCASE) has been extremely successful this year, releasing Version 1.0 of the SEBoK and GRCSE, and is moving toward completion. SERC was also well represented at the NDIA Systems Engineering Conference.

CONDUCT TRANSFORMATIONAL RESEARCH & TRANSITION RESULTS

The SERC research strategy remains solid and stable with consistent validation from our sponsors and others in the community. The interest areas align well with the research recommended by expert panels outside the SERC.

To improve our ability to transition results as well as enhance our opportunities to collect data from ongoing programs, the SERC has reached out to FFRDCs and other UARCs. We have a new Memorandum of Understanding in place with the MITRE Corporation, and 2013 will see increased interaction with similar organizations.



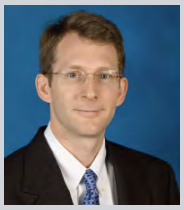
SERC Research Council Members

Dr. Barry W. Boehm
Chairman of SERC Research Council; TRW Professor of Software Engineering and Director, Center for Systems & Software Engineering, *University of Southern California*

Dr. Abhijit Deshmukh
James J. Solberg Head of Industrial Engineering and Professor of Industrial Engineering,
Purdue University

Dr. William Rouse
Alexander Crombie Humphreys Chair of Economics in Engineering and Director of the Center for Complex Systems and Enterprises
School of Systems and Enterprises, Stevens Institute of Technology

Dr. Barry Horowitz
Munster Professor of Systems and Information Engineering and Chair,
University of Virginia



Dr. Jon Wade
Associate Dean for Research,
School of Systems and Enterprises, Stevens Institute of Technology

Making an Impact Through Collaboration

Collaboration is a key tenet of the SERC vision. Creating and sustaining a vibrant and productive collaboration of knowledgeable, experienced and diverse researchers is a world-class challenge by itself. SERC has established an outstanding cooperative of respected institutions that represent an incredibly rich resource of talented, engaged, enthusiastic, and capable researchers. Harnessing those riches without stifling their creativity or enthusiasm requires constantly maintaining communication across a variety of subjects: incentivizing new work to be established through the SERC rather than independently; maximizing every collaborator's ability and desire to bring ideas to the table; protecting intellectual property while encouraging open discussion and shared knowledge; and, understanding the strengths of each organization, creating well-matched teams of collaborators to tackle the most valuable research topics in a financially strapped government environment.

The SERC sponsors have amended some contractual language that made it difficult for two of the original universities (Massachusetts Institute of Technology and the University of California San Diego) to participate in SERC research. We have expanded our diversity with the addition of a significant research resource from the historically black university North Carolina A&T State University. We have engaged in new research with Georgetown University, taking advantage of its work on socio-technical systems and proximity to policy makers throughout the federal government.

Many SERC projects involve PhD candidates who use SERC work as part of their dissertation research. Expedited Systems Engineering drew many of its researchers from students enrolled in a master's degree program at the Air Force Institute of Technology (AFIT)—a SERC collaborator.

"This research was a lot of fun—and to be honest, I refer to it all the time (philosophically speaking) as I work my programs. Our results certainly guide my processes and approach"

Major Ryan M. Colburn, AFLCMC/HBQIX

Another way we are promoting broader collaboration is through appropriately sharing research activities and outcomes with colleges outside of the SERC. The SE Capstone project, currently in its third year, included 14 undergraduate educational institutions, eight civilian and six military academies. More than 360 students participated in this project. We are investigating other ways to share courses between SERC institutions to increase academic collaboration.

SERC DOCTORAL FELLOWS PROGRAM

The Systems Engineering Research Center (SERC) announces the formation of the SERC Doctoral Fellows Program to facilitate workforce development and research transition opportunities with practitioners in US industry, FFRDCs, national laboratories, and government. Through the program, the SERC provides a unique opportunity for future systems engineers to simultaneously develop their abilities and establish one-on-one relationships with thought leaders who serve as mentors. The Boeing Company and the MITRE Corporation are the first organizations to join the new program.

Participating organizations will select employees to become doctoral students with a focus on systems-related research that is in alignment with the SERC's vision. Organizations implement this commitment through their normal internal tuition reimbursement programs and supplement this with 20% release time allowing the employee to dedicate time to the doctoral studies and research in close collaboration with SERC experts.

External SERC Research Participants:

Sweet Briar College · Tuskegee University · Smith College · University of Hawai'i at Mānoa · West Point, The United States Military Academy · University of Rhode Island · Connecticut College

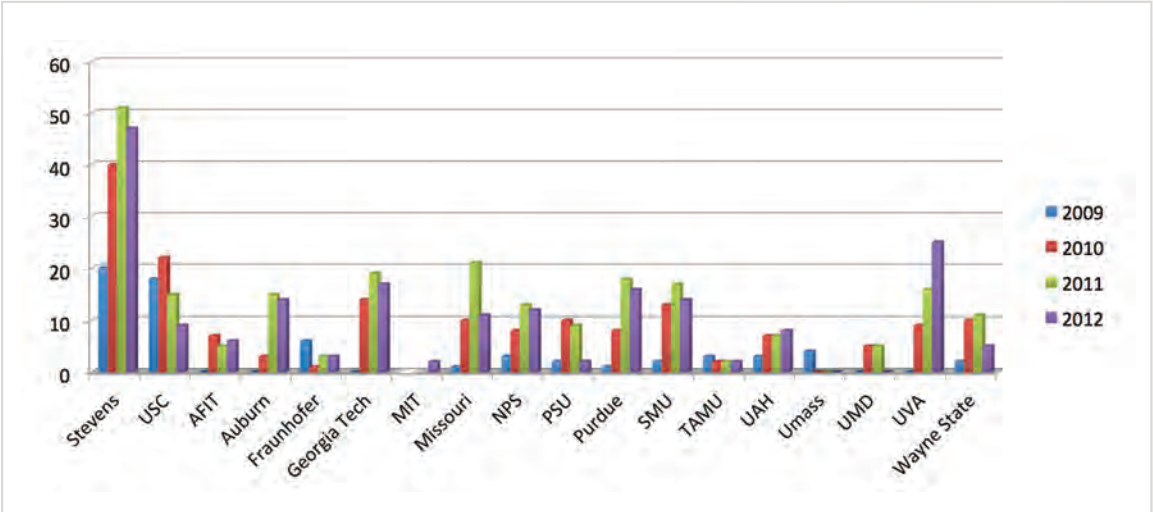
Maintaining Visibility

This year, the SERC responded to sponsor concerns about the length and cost of the Annual SERC Research Review (ASRR) with a radical alternative to a traditional conference-like review. Rather than a single event to address an immense amount of technical material while providing a venue that supported dialogue among sponsors and researchers, the SERC has implemented a sequence of specialized events.

The initial meeting was a half-day SERC Sponsor Research Review in November. Hosted by Georgetown University, this event focused on sharing SERC research priorities, progress and impact, and engaging the sponsor community to discuss needs, gaps, and opportunities. To facilitate this engagement, a SERC Open House and Poster Session encouraged researchers and sponsors to have a substantive conversation about the research—something rarely afforded by traditional review presentations.

A key factor in the decision to split the ASRR was the surprising prevalence of SERC research at the Conference on System Engineering Research last year in St. Louis. At CSER 2012, SERC universities comprised 38% of the accepted papers, 50% of the session chairs, 29% of the plenary speakers, and 25% of the panelists. Given the degree of SERC involvement, it seemed that aligning the technical portion of the ASRR with the CSER was an economical way of briefing not only the sponsors, but also maintaining SERC visibility throughout the systems engineering community. The SERC technical reviews will be part of the CSER 2013 March 19-22 at Georgia Tech in Atlanta.

Researchers by institution by year



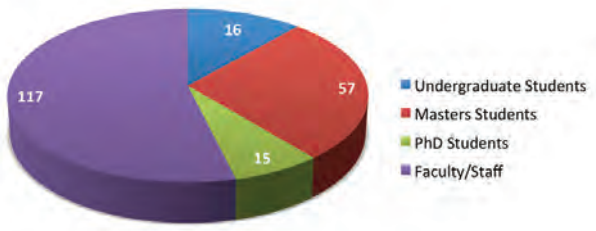
SERC Operational Accomplishments

In September 2012, the SERC completed its fourth year of operations. The SERC continued along its steady path of sustainable and efficient operations and deepened its strategic partnership with the DoD. The SERC, unlike other University Affiliated Research Centers (UARCs), is not just a single university or a small handful of universities—it is a vibrant collaboration that provides the government broad access to systems researchers and students across the nation. The SERC network of collaborating universities continued to strategically expand in 2012, with the addition of Georgetown University, North Carolina Agriculture and Technical State University and Massachusetts Institute of Technology. Moreover, the University of California San Diego stepped up to become a fully participating collaborator.

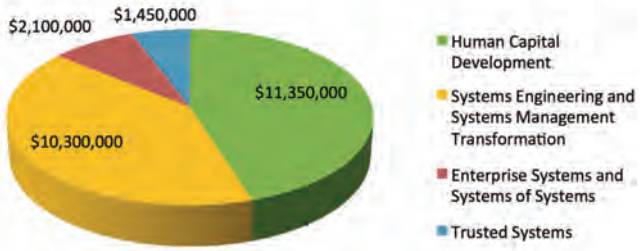
Among the many operational milestones for the SERC in 2012:

- Total awards passed the $25 million mark.
- The number of researchers and students who have worked on SERC projects since 2008 climbed past 350.
- Journal and conference publications grew to more than 65.
- The Annual SERC Research Review evolved into a new format that includes a compact meeting in the fall for sponsors and a substantial technical exchange in the spring as part of the Conference on Systems Engineering Research.
- More than 20 research tasks executed.
- The research portfolio continued to align and mature around the four thrusts described in the SERC research strategy.
- Classified research was authorized and will begin in 2013.
- Projects continued to shift towards longer higher-impact multi-year efforts.
- The SERC's primary sponsor is planning to provide more substantial annual core funding.

Types of Researchers



Funding by Research Area



$25,200,000 awarded during the period Oct. 1, 2008 to Dec. 31, 2012

The SERC used several measures to gauge its progress, including:

SERC STRATEGY	MEASURE	EXAMPLE
Create Research Ecosystem	Conduct research that builds on work being funded by others, creating larger, more impactful projects	The Tradespace and Affordability Project (RT-46) is building on several non-SERC funded collaborator efforts, such as MIT's Epoch-Era Analysis, and is working with DoD's Engineered Resilient Systems Program.
Conduct Transformational Research	Extend research projects by continuing to fund additional research stages or spinning off new projects. Publish peer-reviewed papers in journals, conferences, and books.	In 2012, more than $4M in additional funding was applied to existing projects or to start spin-off projects. More than 20 papers were published, such as RT-30's "Developing a Stakeholder-Assisted Agile CONOPS Development Process," which appeared in the Systems Engineering Journal.
Transition Results into Impact	Integrate research results into collaborator courses.	Numerous courses across the collaborators integrated the results of RT-19's SE Capstone; Purdue integrated results from RT-36's SoS Analytic Workbench Project into their AAE560 course on SoS Modeling and Analysis.

SERC Research Highlights

MULTI-LEVEL MODELING OF SOCIO-TECHNICAL SYSTEMS

- **PI:** Dr. William Rouse, Stevens Institute of Technology
- **Sponsor:** DASD(SE)
- **Collaborators:** Dr. Douglas Bodner, Georgia Tech

Enterprise & SOS

Over several decades, the Department of Defense has invested $10B developing computational models and simulations of complex military systems. These estimated 8,000 software artifacts model everything from weapon platforms to operational military organizations. Unfortunately, they rarely interact with each other. Existing capabilities must be enhanced to allow models of different levels of fidelity to interoperate in a dynamic fashion.

To see if commercial practice provides such integration, the SERC conducted a series of interviews with eight executives in four industries—automobile, commercial aerospace, building equipment, and semiconductors and electronics.

The interviews provided the following insights:

- While all the industries used modeling tools at a variety of levels, there is little computational linkage, due in part to organizational attributes.
- All the industries recognized the importance of socio-technical phenomena, but seldom integrate such models into decision models.
- Modeling and simulation are primarily driven by significant manufacturing efforts.

The next phase of this project, launched in September, will attempt to develop an integrating framework. It will formulate a multi-level model, (including alternative representations and approaches) and design a human-computer interface with rich visualizations and scenario building controls.

SYSTEM OF SYSTEMS (SOS) ANALYSIS

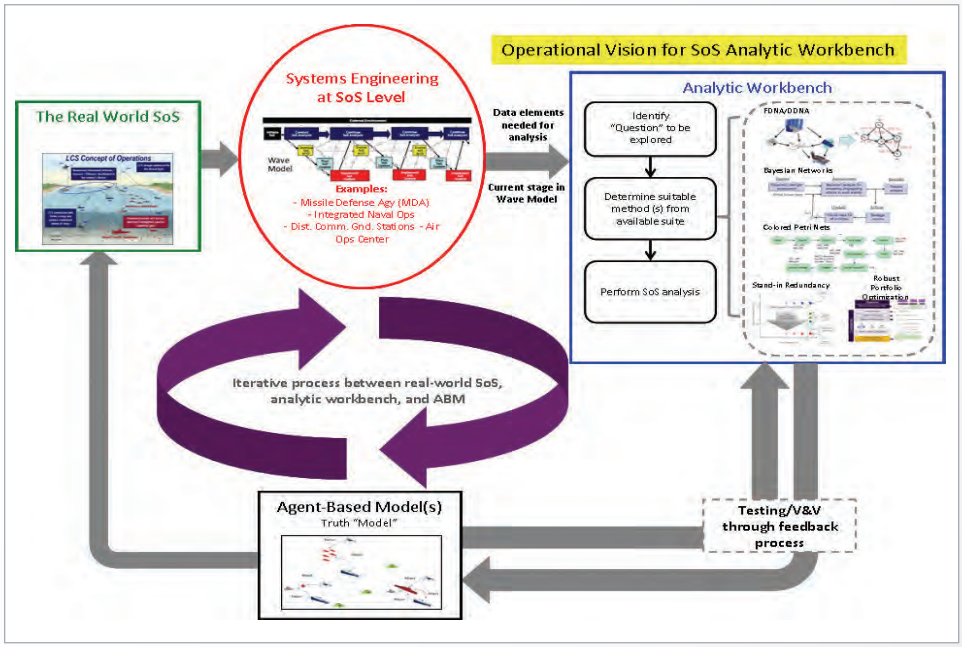
- **PI:** Dr. Daniel DeLaurentis, Purdue University
- **Sponsor:** DASD(SE)
- **Collaborators:** Dr. Karen Marais, Purdue University

Enterprise & SOS

Developing a System of Systems (SoS) remains a highly challenging endeavor. The complex interdependencies among systems often exhibit managerial and operational independence, yet must work cohesively to achieve an overarching set of capabilities. This research addresses a need to create and mature decision- support tools specifically for evolving SoS architectures; in particular, those that support assessing the impact of potential disruptions during development or operation.

Trades between capability and risk are essential decisions that must be addressed for SoS capability planning. Existing tools for such trades are of limited value when size and/or interdependency complexity is high. This research explored analytical methods to quantify the impact of system interdependencies in the context of SoS capability development.

The research centered on seven analytical methods adapted to support SoS architecting decisions and systems engineering of constituent systems. It focused on inputs, outputs, and limitations in the context of support for the "Wave" model for SoS architectural evolutions. The work also experimented with the methods on a naval surface warfare scenario involving the Littoral Combat Ship (LCS). The research shows great promise in supporting relevant analysis and evolution of SoS architectures; these methods will be further matured and enhanced in follow-up research work.

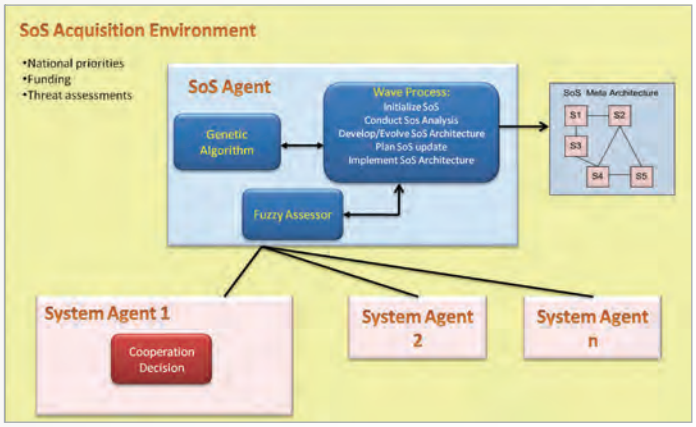


SERC Research Highlights

SOS ANALYSIS USING AGENT-BASED BEHAVIORAL MODELING

- **PI:** Dr. Cihan Dagli, Missouri University of Science and Technology
- **Sponsor:** DASD(SE)
- **Collaborators:** Pennsylvania State University, Air Force Institute of Technology

Enterprise & SOS



This research project focuses on identifying innovative approaches to support SE in architecting, engineering, and evolving complex SoS. It seeks to develop practices and tools that can characterize complex SoSs, dynamically analyze and assess SoS performance under changing conditions and scenarios, develop SoS architectures that effectively address the independent nature of constituent systems and their unanticipated change, and improve user capabilities given SOS complexities and risks.

A proof-of-concept agent-based model has been developed that accounts for the ability and willingness of constituent systems to support SoS capability development. The model simulates SoS creation and evolution using a genetic algorithm to explore the potential architectural design space and a fuzzy associative memory to evaluate candidate architectures. It evaluates the capability of the evolving SoS architecture with respect to four attributes: performance, affordability, flexibility, and robustness. The method is applied to an acknowledged intelligence, surveillance, and reconnaissance SoS as an example domain. Research continues to enhance the usefulness of the model.

SYSTEM AWARE CYBER SECURITY

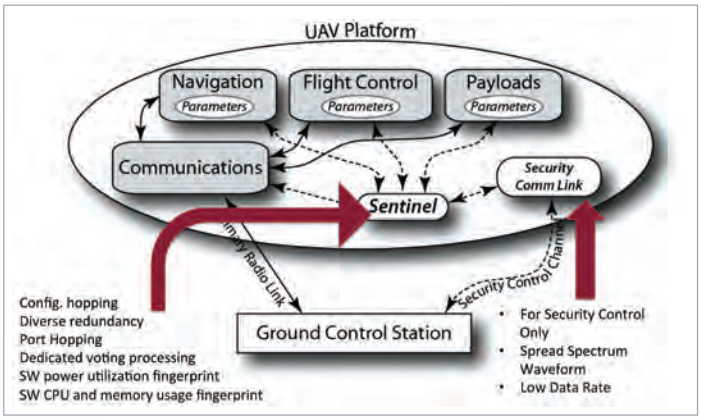
- **PI:** Dr. Barry Horowitz, University of Virginia
- **Sponsor:** DASD(SE)
- **Collaborators:** Georgia Tech

Trusted Systems

The Systems Engineering Research Center (SERC) has been engaged with the DoD in developing a novel cyber security concept for embedding security solutions into systems. These solutions provide greater assurance to the most critical system functions, complementing perimeter and network security solutions that serve to guard the entire system from penetration. In addition, the System Aware cyber security solutions guard against insider and supply chain attacks that circumvent perimeter security solutions.

Current research is exploring the feasibility of applying security engineering design patterns and a scoring system to evaluate architectural trades through development of an unmanned autonomous system (UAS) that can accommodate a variety of payloads. The pilot project is utilizing the Griffon Aerospace MQ-170 Outlaw UAV and payloads available through Georgia Tech. The UAS development should identify unique engineering problems that require special application-specific adaptations to the proposed methods and an emerging understanding of critical design issues. These will lead to a better estimate of the feasibility of practical system-aware solutions.

The security architecture for the UAS will be derived from design patterns developed under previous SERC work. A variety of security design patterns will be evaluated as competing alternatives, and a subset of the most desirable will be developed and integrated onto the UAS for test and evaluation. The remaining parts of the security architecture will be implemented and evaluated through use of simulation. Real and emulated technology demonstrations will be evaluated against simulated, multiple attack scenarios, such as supply chain insertion of malicious components, and exploitation of COTS configuration flaws during operations.



-ILITIES TRADESPACE AND AFFORDABILITY PROGRAM (ITAP)

- **PI:** Dr. Barry Boehm, University of Southern California
- **Sponsor:** DASD(SE)
- **Collaborators:** Air Force Institute of Technology, Georgia Tech, Massachusetts Institute of Technology, Naval Postgraduate School, Stevens Institute of Technology, University of Virginia, Wayne State University

SE & SM Transformation

Through several recent initiatives, the DoD has increased its emphasis on the affordability of its systems. Many critical affordability challenges come from problems in engineering the most effective levels of the system's "ilities" or non-functional requirements (e.g. reliability, availability, security, scalability). Unlike functional requirements, which only add expense incrementally, the ilities have a systemic scope that can yield extreme effects on cost.

A SERC workshop was held to explore candidate areas of tradespace and affordability research, leveraging a previous DoD-wide Engineered Resilient Systems tradespace workshop. The workshops concluded affordability was not only concerned with acquisition costs, but also with total ownership costs across the life cycle, and the costs of ensuring mission effectiveness. Given the increasingly rapid pace of changes in technology, threats, and mission priorities, cost analyses need to address uncertainty considerations, as well. Previous SERC research tasks (Valuing Flexibility, Expedited SE, Lean and Agile SE, and Next-Generation Cost Models), along with other DoD research have addressed modeling this tradespace. The newly initiated ilities Tradespace and Affordability Program (iTAP) will build on existing research, creating a flagship research project for the SERC SE and SM Transformation research area.

The first phase consists of (1) developing an understanding of the different DoD stakeholder priorities for the ilities, (2) developing of viewpoint frameworks for understanding and making trades against such factors, and (3) creating initial demonstration capabilities based on the selected collaborator research base. The second phase will focus on integrating the viewpoint frameworks into an ilities counterpart and on extending, piloting, refining, and exploring interoperability among the strongest of the Phase 1 demonstration capabilities.

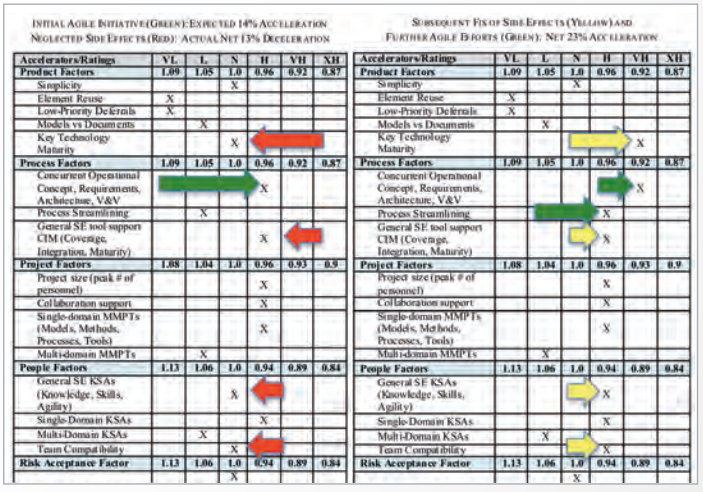
QUANTITATIVE SCHEDULE ACCELERATION MODEL

- **PI:** Debra Lepore, Stevens Institute of Technology
- **Sponsor:** SAF/AQR
- **Collaborators:** University of Southern California, Air Force Institute of Technology

SE & SM Transformation

Accelerating development and deployment schedules is a continuing challenge. Reduced time-to-market is a key response to competitive threats in the commercial sphere. Rapid response in deploying military systems may save lives and deter adversaries in a rapidly evolving geopolitical environment. Agile/lean development methodologies show promise in providing the desired schedule acceleration. However, many projects experience slower schedules by jumping into agile methods without awareness of their associated pitfalls. This project provides a quantitative model that not only helps estimate actual reductions in schedule, but also engages the user in identifying and understanding the risks and opportunities associated with agile approaches.

The Constructive Rapid Application Development Model (CORADMO) attempts to quantify both the positive and the negative effects of key schedule drivers, enabling planners to vary these parameters and see the schedule impact. CORADMO is a derivative of the revised Constructive Cost Model (COCOMO II), a model calibrated against larger projects typically optimized to reduce cost. The goal of projects using agile/lean techniques is often to compress schedule, and, until recently, there was not a critical mass of data to calibrate such a model. Research on expediting systems and software engineering via lean and agile methods has led to an expanded set of product, process, project, people, and risk factors that account for relative schedule acceleration and deceleration. These were formalized into schedule acceleration drivers for a model that was calibrated to explain the results of a dozen projects from a successful agile development corporation. The resulting model and an example of its use are shown below.



Initial Agile Initiative (Green): Expected 14% Acceleration
Neglected Side Effects (Red): Actual Net 13% Deceleration

Accelerators/Ratings	VL	L	N	H	VH	XH
Product Factors	1.09	1.05	1.0	0.96	0.92	0.87
Simplicity			X			
Element Reuse	X					
Low-Priority Deferrals	X					
Models vs Documents		X				
Key Technology Maturity			X	←		
Process Factors	1.09	1.05	1.0	0.96	0.92	0.87
Concurrent Operational Concept, Requirements, Architecture, V&V	→			X		
Process Streamlining		X				
General SE tool support CIM (Coverage, Integration, Maturity)				X	←	
Project Factors	1.08	1.04	1.0	0.96	0.93	0.9
Project size (peak # of personnel)				X		
Collaboration support				X		
Single-domain MMPTs (Models, Methods, Processes, Tools)				X		
Multi-domain MMPTs		X				
People Factors	1.13	1.06	1.0	0.94	0.89	0.84
General SE KSAs (Knowledge, Skills, Agility)				X	←	
Single-Domain KSAs				X		
Multi-Domain KSAs		X				
Team Compatibility			X	←		
Risk Acceptance Factor	1.13	1.06	1.0	0.94	0.89	0.84
			X			

Subsequent Fix of Side Effects (Yellow) and Further Agile Efforts (Green): Net 23% Acceleration

Accelerators/Ratings	VL	L	N	H	VH	XH
Product Factors	1.09	1.05	1.0	0.96	0.92	0.87
Simplicity			X			
Element Reuse	X					
Low-Priority Deferrals	X					
Models vs Documents		X				
Key Technology Maturity			→	X		
Process Factors	1.09	1.05	1.0	0.96	0.92	0.87
Concurrent Operational Concept, Requirements, Architecture, V&V			→	X		
Process Streamlining			→	X		
General SE tool support CIM (Coverage, Integration, Maturity)			→	X		
Project Factors	1.08	1.04	1.0	0.96	0.93	0.9
Project size (peak # of personnel)				X		
Collaboration support				X		
Single-domain MMPTs (Models, Methods, Processes, Tools)				X		
Multi-domain MMPTs		X				
People Factors	1.13	1.06	1.0	0.94	0.89	0.84
General SE KSAs (Knowledge, Skills, Agility)			→	X		
Single-Domain KSAs				X		
Multi-Domain KSAs		X				
Team Compatibility			→	X		
Risk Acceptance Factor	1.13	1.06	1.0	0.94	0.89	0.84
			X			

SERC Research Highlights

SYSTEMS ENGINEERING CAPSTONE MARKETPLACE

- **PI:** Dr. Mark Ardis, Stevens Institute of Technology
- **Sponsor:** DASD(SE)
- **Collaborators:** Stevens Institute of Technology, University of Alabama in Huntsville, Southern Methodist University, Missouri University of Science and Technology, University of Hawaii at Manoa

Human Capital Development

Previous SERC research has shown that multidisciplinary capstone programs can enhance development of SE competencies. Capstone sponsors typically want projects that draw expertise from a variety of disciplines.

Undergraduate capstone courses, however, often focus on one discipline oriented to the academic department sponsoring the course. Universities with small engineering programs may conduct multidisciplinary capstone projects out of necessity; however, they often lack the resources to provide students a challenging, real-world experience. This research task investigates establishing a marketplace for undergraduate capstone projects that emphasizes multidisciplinary projects involving th development of systems engineering competencies.

As conceived, this marketplace will improve and accelerate the development of broad systems thinking. It will also:

> Engage a variety of stakeholders from government, industry, and academia to propose challenging projects requiring cross-discipline systems thinking

> Allow students to self-organize and select projects addressing their backgrounds and interests

> Support faculty to focus on guiding student learning rather than defining projects and obtaining necessary resources

SYSTEMS ENGINEERING WORKFORCE EVOLUTION – THE HELIX PROJECT

- **PI:** Dr. Art Pyster, Stevens Institute of Technology
- **Sponsor:** DASD(SE), NDIA Systems Engineering Division
- **Collaborators:** Stevens Institute of Technology

Human Capital Development

Many systems engineers in the defense workforce are nearing retirement. Budget and schedules are being dramatically compressed. Mission requirements demand ever more sophisticated and complex systems. The tools, processes, and technologies that systems engineers must master change to meet evolving demands. There is scant agreement or understanding around what makes an effective systems engineer, how to measure their effectiveness, or how to evaluate current SE workforce improvement efforts.

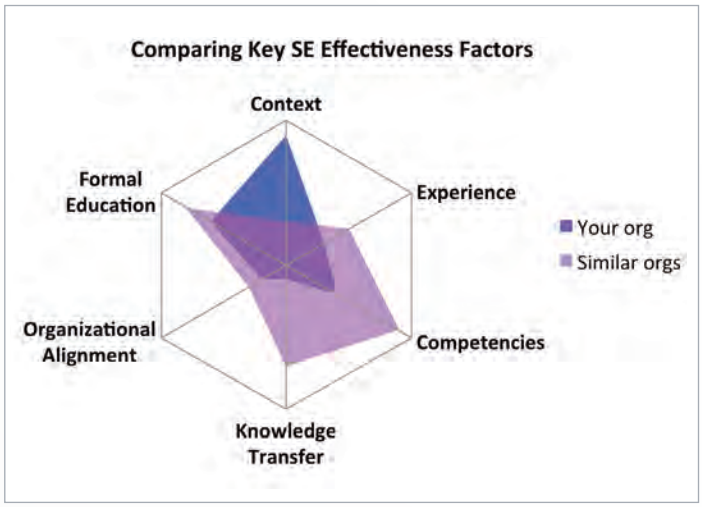
The Helix Project, sponsored by the DoD and the National Defense Industrial Association Systems Engineering Division, is a multi-year study to determine the effectiveness and demographics of systems engineers in the US Department of Defense and defense community. It will answer three questions:

> Who are the systems engineers?

> How effective are they and why?

> What are employers doing to improve their effectiveness?

Beginning in the second half of 2013, Helix will publish quarterly reports answering these three questions. Each report will include new insights gained from the previous quarter's data collection. The reports will identify the highest-leverage factors (such as experiences, education, and competencies) and the most effective strategies to address them. Helix data will eventually provide benchmarks for different segments of the SE community as well as individual organizations.



Updates on Continuing SERC Research

BKCASE

Human Capital Development

In 2012, the BKCASE project, led by Dr. Art Pyster (Stevens) and Dr. Dave Olwell (NPS), celebrated several major milestones. The team of over 70 volunteers from around the world released three versions of the Guide to the Systems Engineering Body of Knowledge (SEBoK): a draft version for review in March, the first official release of the SEBoK in September, and a micro-release to correct minor issues in November. Between September and the end of 2012, the official releases of the SEBoK, which were published as wikis, were viewed by over 16,000 users. In December, the BKCASE team published the final official version of the Graduate Reference Curriculum for Systems Engineering (GRCSE). The International Council on Systems Engineering (INCOSE) recognized both of the BKCASE products—SEBoK and GRCSE—as "Product of the Year" for 2012.

Pyster and Olwell accepting the 2012 Product of the Year Award from INCOSE President John Thomas

EXPERIENCE ACCELERATOR

Human Capital Development

The Experience Accelerator hopes to "effectively compress time and greatly accelerate the learning of a systems engineer faster than would occur naturally on the job." In its second year, the program focused on the improvement and refinement of the initial prototype. Significant progress was made in the areas of experience design, tools capability, technology development, simulation capability, and development process. Continuing work on pilots and tools addresses the validation of overall effectiveness, the improvement of new experience creation efficiency, and "multi-player" capabilities. The objective is to integrate the Experience Accelerator into a Defense Acquisition University course for the Fall 2013 semester. Research will continue in the effort to determine how to measure the Experience Accelerator's ability to "effectively compress time and greatly accelerate the learning of a systems engineer."

RAPID GRAPHICAL CONOPS DEVELOPMENT

SE & SM Transformation

Begun in 2009, this ongoing research will demonstrate the ability to rapidly develop a concept of operations using a 3D modeling environment. In 2012, the existing team was expanded to include researchers in human factors analysis and gaming technologies. An agile development approach was successfully implemented across two universities and the DoD sponsor. Significant milestones this year include: a fully functional, open source database that provides model persistence; placeholders in scenes when a desired object is not in the library; data logging; modified animation/playback architecture; and improved physics engine and animation, including improved drag-and-drop capabilities. The team has defined and development metrics for the measurement and assessment of the approach.

SE FOR AN AGILE AND LEAN WORLD

SE & SM Transformation

The Expedited Systems Engineering team completed its first phase and delivered a final report in December. Based on a review of current literature, and observing and interviewing 25 rapid development projects, the team constructed an initial framework of rapid development principles. Broken into three mutually supporting components, the framework provides a means of organizing observations and practices that can expedite SE.

Building on its research into applying agile and lean concepts to SE, the Kanban in Systems Engineering project refined its on-demand scheduling and SE-as-a-services approach to coordinate large multi-level systems development and evolution projects. It developed an example implementation for a multi-facility health care provider. This example showed that the approach improves visibility of effort and status throughout the development. Further research into these aspects is anticipated in 2013.

Research Tasks Completed in 2012

TITLE	PRINCIPAL INVESTIGATOR
Valuing Flexibility	Abhi Deshmukh
Vehicle Systems Engineering and Integration Activities	Walter Bryzik
Systems Engineering Assessment & Workforce Development Plan	Brian Sauser
Contingency Basing	Brian Sauser
Expedited SE	Debra Facktor Lepore
Defining the Meaning of a Major Modeling and Simulation Change as Applied to Accreditation	Julie Fortune / Mikel Petty
Systems Engineering and The Cloud	Chris Ackerman

SERC Advisory Board

The Honorable Michael Wynne, Chair

Mr. Wynne is a senior advisor to Stevens Institute of Technology and serves as the Chair of the Advisory Board for the Systems Engineering Research Center. He was the 21st Secretary of the Air Force, and before that the Undersecretary for Acquisition, Technology and Logistics in the office of the Secretary of Defense, both spanning 2001 to 2008. He served in the Air Force for seven years, finishing as assistant professor of Astronautics at the Air Force Academy. He spent three years with Lockheed Martin Corp as the general manager for Space Launch, and 23 years with General Dynamics working in aircraft, armored vehicles, and the space division. He retired as senior vice president from General Dynamics.

Mr. Alfred Grasso

Mr. Alfred Grasso is president and chief executive officer of The MITRE Corporation. He is responsible for developing and leading the corporation's overall strategic and business operations and cultivating key sponsor and customer partnerships. Mr. Grasso is also a member of MITRE's Board of Trustees. Mr. Grasso is a member of the Defense Science Board, vice chair of the Armed Forces Communications and Electronics Association (AFCEA) International Board of Directors. He is a special advisor to the STRATCOM CYBER Strategic Advisory Group.Mr. Grasso is the president of the Board of Directors of the National GEM Consortium, a nonprofit that works to promote the participation of under-represented groups in science, technology, engineering, and mathematics (STEM) careers.

Major General Nick Justice

Major General Nick Justice retired from the United States Army after serving over 42 years as an American soldier. He began his Army career as an enlisted soldier. His experiences opened new doors in high performance computing, electronic warfare, telemetry analysis, telecommunications, as well as experiences in legal and leadership in the infantry. Highlights of his career include assignments with NATO during Dessert Storm where he built command and control systems; Project Manager for Force XXI Battle Command Brigade and Below, fielding systems during Operation Iraqi Freedom; Program Executive Officer for Tactical Command and Control Systems; and the Commanding General of the Army Research, Development, & Engineering Command and the Aberdeen Proving Ground.

Dr. Ruth David

Dr. David is president and CEO of Analytic Services Inc. Prior to ANSER, she was Deputy Director for Science and Technology at the Central Intelligence Agency and was awarded the CIA's Distinguished Intelligence Medal, the CIA Director's Award, the Director of NSA Distinguished Service Medal, the NRO's Award for Distinguished Service, and the Defense Intelligence Director's Award.
Dr. David is a senior fellow of the Defense Science Board, a member of the Department of Homeland Security Advisory Council, the National Security Agency Advisory Board, the Corporation for the Charles Stark Draper Laboratory, Inc., and the Hertz Foundation Board. She was elected into the National Academy of Engineering in 2002 and currently serves as a councilor of the NAE, chairs the National Research Council (NRC) Board on Global Science and Technology, chairs the NRC Standing Committee on Technology Insight–Gauge, Evaluate, and Review (TIGER), and is a member of the Standing Committee on Science, Engineering, and Public Policy (COSEPUP).

Mr. John G. Grimes

Mr. Grimes served as the Assistant Secretary of Defense for Networks and Information Integration / Department of Defense Chief Information Officer from 2005 until 2009. Prior to that, he served on the White House National Security Council Staff as Director for National Security Telecommunications Policy; Director of Defense Command, Control and Communications Programs; and Senior Director White House Situation Support Staff. Mr. Grimes has served as Deputy Assistant Secretary of Defense for Defense-wide Command, Control and Communications and was the Deputy Assistant Secretary of Defense for Counter-intelligence and Security Countermeasures. He is the recipient of the AIAA Command, Control, Communications and Intelligence Award, the 2010 AFCEA SARNOFF Award, and two U.S. Presidential Rank awards.

William M. Shepherd

CAPT Shepherd is a retired Navy SEAL and United States Astronaut. He was a SEAL platoon commander and operations officer. Shepherd was selected for the NASA astronaut corps in 1984. He completed three flights as a mission specialist on STS-27 Atlantis, STS-41 Discovery, and STS-52 Columbia, and was the commander of the Expedition-1 crew on the International Space Station. In 1993, CAPT Shepherd was assigned as the Program Manager for the International Space Station. He retired from active duty in 2002, and served at USSOCOM from 2008 to 2011 as Science Advisor, where he managed the Special Operations Forces' science and technology portfolio.
Capt. Shepherd's awards include the National Intelligence Medal, NASA's "Steve Thorne" Airmanship Award, the Komarov Diploma, the Spirit of St. Louis Medal, the Gagarin Gold Medal, the Robert H. Goddard Trophy, and the Congressional Space Medal of Honor. Capt. Shepherd was recently designated "Honorary Naval Aviator Number 30" by the Chief of Naval Air Warfare.

About the SERC

The Systems Engineering Research Center (SERC), a University-Affiliated Research Center of the US Department of Defense, leverages the research and expertise of senior lead researchers from 23 collaborator universities and not-for-profit research organizations throughout the United States. The SERC is unprecedented in the depth and breadth of its reach, leadership, and citizenship in Systems Engineering. Led by **Stevens Institute of Technology**, and principal collaborator, the **University of Southern California (USC)**, the SERC provides a critical mass of systems engineering researchers—a community of broad experience, deep knowledge, and diverse interests. SERC researchers have worked with a wide variety of domains and industries, and so are able to bring views and ideas from beyond the traditional defense industrial base. Establishing such a community of focused SE researchers, while difficult, promises results well beyond what any one university could accomplish.

BECOMING A SPONSOR

By becoming a SERC research sponsor, US Government organizations can easily engage more than 150 thought leaders at 20 leading research and academic institutions to solve complex, contemporary systems engineering problems. The process begins when an organization identifies a problem requiring SE research. They should contact the SERC to discuss the problem and determine if it is within the scope of the SERC's mission. If it is, then the organization refines the research need and the SERC responds with its technical approach, cost estimate, and potential value for the research. The SERC then selects a Principal Investigator and a team of the most appropriate researchers to perform the research and deliver the results and value to the funding organization. Unless specifically limited, the results are published and available for inclusion in education and transition activities across the systems engineering community.

WORKING WITH THE SERC

While the existing SERC collaborators already represent a significant portion of the systems and software engineering research talent in the United States, there are opportunities for other academic or industry research centers to participate in SERC activities. To discuss this possibility please contact a member of the SERC Leadership Team.

SYSTEMS ENGINEERING
Research Center

LEADERSHIP

Executive Director
Dr. Dinesh Verma, Dean and Professor, School of Systems and Enterprises, Stevens Institute of Technology

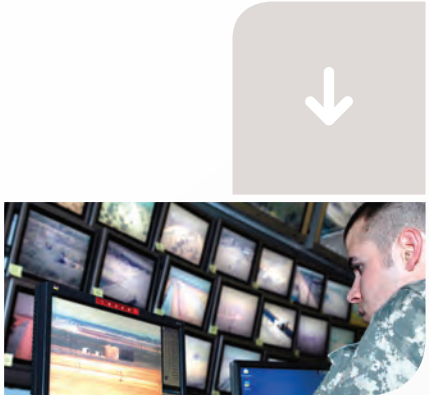
Deputy Executive Director
Dr. Arthur Pyster, Distinguished Research Professor, School of Systems and Enterprises, Stevens Institute of Technology

Chairman of Research Council
Dr. Barry Boehm, Director Emeritus of the Center for Systems and Software Engineering and TRW Professor of Computer Science, University of Southern California

Director of Strategic Programs
Ms. Debra Facktor Lepore, Industry Professor and Technical Leadership Program Director, Stevens Institute of Technology

Director of Technical Programs
Dr. Stan Rifkin, Research Professor, Stevens Institute of Technology

Director of Operations
Ms. Doris Schultz, Stevens Institute of Technology



The SERC Collaborators

University or Research Organization

1. Stevens Institute of Technology
2. University of Southern California
3. Air Force Institute of Technology
4. Auburn University
5. Carnegie Mellon University
6. Fraunhofer Center at University of Maryland
7. Georgetown University
8. Georgia Institute of Technology
9. Massachusetts Institute of Technology
10. Missouri University of Science and Technology
11. Naval Postgraduate School
12. North Carolina Agricultural & Technical State University
13. Pennsylvania State University
14. Purdue University
15. Southern Methodist University
16. Texas A&M University
17. Texas Tech University
18. University of Alabama in Huntsville
19. University of California - San Diego
20. University of Maryland
21. University of Massachusetts Amherst
22. University of Virginia
23. Wayne State University

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